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The effect of Lumbricidae on the barley crops in various soils

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With 4 figures

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Synopsis

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On the basis data obtained from experiments carried out in different soils of vegetative pots in 1962—1967, a positive influence of Lumbricidae, on barley crops is shown. The latter increased proportionally according to the numbers of Lumbricidae on barley crops in the different soils and depended on the survival of the earthworms in the vegetative pots.

Исходя из данных исследований, проведенных в 1962—1967 гг. в вегетационных сосудах установлено, что дождевые черви оказывают положительное влияние на урожай ячменя. Урожай ячменя пропорционально увеличивается в зависимости от числа червей. Влияние дождевых червей на урожайность ячменя в различного типа почвах неодинакова и зависит от выживаемости червей в вегетационных сосудах.

1. Introduction

The activity of Lumbricidae exerts a great influence on the soil aeration, structure and the humification and fermentation processes which improve and enrich the soil itself. Satchell (1958) and Chekanovskaja (1960) mentioned several investigations that have shown the positive effect on the crops of various plants. By his extensive experiments Zraževskij (1957) proved that Lumbricidae had an effect on the wood tree seed germination and the growth of the young trees. Archangelsky (1929) investigated the effect of Lumbricidae on oat and barley crops when soil was fertilized by straw, green lupine, bone and blood flour and found the earthworm influence to be a positive one. Dadykin (1941), Balujev (1950) investigated the effect of Lumbricidae on oat and wheat crops in different kinds of soil. Spannagel (1954) analysed the role of Lumbricidae in the mixing process of different soil layers and the formation of soil structure. He also investigated the effect of earthworms on crops of the plants.

There can be no doubt that Lumbricidae raise the crop figures but in addition there are many questions to be answered concerning the effect of Lumbricidae on the plants.

More information is required on the activity of different species of Lumbricidae and the densities that are the most effective for plant crop increase. There is little information on the activity of Lumbricidae and their effect on the plant crops in different soils.

2. Methods

The influence of Lumbricidae on the barley crops was investigated in the different soils of vegetative pots during one season of 1—3 years in 1962—1967. In the vegetative clay pots 5 litres in volume, 21 cm in diameter were placed 2—6 kg of sieved soil and several specimens of earthworms. The experiments had 1—5 replications and 4 variants:

1) control (no earthworms) — K;
2) experimental group with 4 earthworms;

3) experimental group with 8 earthworms and
4) experimental group with 16 earthworms in each pot.

The following species of Lumbricidae were used: *Allolobophora caliginosa* — Ac, *Lumbricus rubellus* — Lr and *Lumbricus terrestris* — Lt. The earthworms put in the vegetative pots had the following densities in 1 m^2, of soil: 115 (4 earthworms), 230 (8 earthworms) and 460 (16 earthworms). These numbers simulate the natural distribution of earthworms in soils except where there were 16 earthworms in a pot; the latter number was almost twice as big as that representing the natural amount of earthworms in our investigated soils.

Soil samples were taken from various plots with known soil characteristic (Table 1).

Table 1 The soils in which the effect of Lumbricidae on the barley crops was investigated

No.	Soil specification	Abbreviated soil specification	*p*H	Humus %
1	Soddy podzolic sandy loam	V	5.3	2.4
2	sandy loam	Vr	5.8	2.8
3	Soddy podzolic clay loam	D	5.1	1.3
4	clay loam	M	4.3	1.6
5	Soddy gleyish clay loam	Dt	7.1	1.9
6	Soddy gleyish humus clay loam	K	6.9	7.2

In summer (May—September) these vegetative pots were kept in the open air under the barley culture "Džiugiai". Barley vegetation period — 3 months (May—August). When the experiment lasted for 2—3 years the vegetative pots were kept in hothouses at 10—16 °C during the winter period (in October—April). Lumbricidae were examined in the vegetative pots during the period of 3—6 months. In the case when earthworms vanished their numbers were correspondingly (4; 8; 16) supplemented from outside.

The soil used in the experiments (in 1965—1967) was partly fertilized by minced barley straw (60 g per pot) out in 3—5 cm lengths. In autumn the straw was placed 5—10 cm below the surface while in summer it was placed in soil 5—10 cm above the bottom of the pots.

3. Results

All the experiments performed show the positive influence of Lumbricidae on the barley crops. In comparison with the crops in the control pot the barley crops increased according to the numbers of the earthworms added. In the experimental variants when the number of Lumbricidae was four, barley grain crops were 101.5—191.7 per cent bigger than those of the control group (100 per cent) except some cases when 4 earthworms had no effect whatsoever on the barley crops. In the vegetative pots where there were 8 earthworms the crops were 107.5—287.4 per cent higher while 16 earthworms made the crops 115.7—301.1 per cent bigger than those of the control group.

Where 8 or 16 earthworms were put in the respective soil barley crop in the pots increased in some cases up to 2 times (Table 2).

The effect of Lumbricidae on the barley crop is considerable both in the case of total weight of barley green mass and in the case of the weight of the grains alone. But often the effect on the weight of the grains was more marked than that on the total weight of barley green mass. Only rarely was the effect of Lumbricidae the same both on the grain crop and the total weight of barley green mass (Table 3). Dadykin (1941) has also pointed out that the effect of Lumbricidae was more marked on the grain crop than on that of other parts of the plant.

It was observed that the positive effect of Lumbricidae on the barley crops lasted not only one vegetative period but up to 3 years (Fig. 1).

When soil in the vegetative pots had been fertilized by straw (60 g per pot) in autumn or in spring before the sowing time, the effect of Lumbricidae on the barley crops was

Table 2 The effect of Lumbricidae on the barley grain crop (per cent)

Series of operation	Soil specification and time of experiment		Soil weight (in kg) in a vegetative pot	The species of Lumbricidae	The number of reiterations of experimental variants	Control	Experimental variants		
	The beginning of the experiment	Crops in different years					The number of Lumbricidae in a vegetative pot		
							4	8	16
	D								
1	1962. V. 24	1962	6.0	Ac	1	100.0	122.2	261.1	127.7
2	1963. V. 27	1963	6.0	Ac	2	100.0	137.1	140.0	165.7
	V								
1	1963. V. 29	1963	6.0	Lt	1	100.0	100.5	127.7	164.8
2	1963. V. 29	1963	6.0	Ac	3	100.0	100.0	129.6	125.9
3*)	1965. X. 20	1966	2.5	Ac	5	100.0	128.2	165.5	205.0
4**1)	1965. X. 20	1967	2.5	Ac	4	100.0	191.7	287.4	255.7
	Vr								
1	1965. VII. 15	1966	4.0	Ac	5	100.0	133.3	131.3	147.0
2	1966. V. 11	1966	4.5	Ac	3	100.0	139.0	158.5	173.1
	K								
1	1966. V. 11	1966	5.3	Ac	2	100.0	114.5	145.5	180.0
2**)	1966. V. 11	1967	5.3	Ac	2	100.0	145.8	155.8	200.0
	K								
1*)	1965. X. 25	1966	5.3	Ac	2	100.0	101.5	130.2	150.0
2**)	1967. V. 5	1967	2.0	Lr	1	100.0	132.8	138.0	115.7
3**)	1967. V. 5	1967	2.0	Ac	2	100.0	141.2	182.1	183.6
4	1967. V. 5	1967	3.6	Ac	5	100.0	153.3	241.0	301.1
	M								
1	1967. V. 5	1967	4.0	Ac	5	100.0	100.0	107.5	134.1
	Dt								
1	1967. V. 5	1967	4.0	Ac	5	100.0	104.4	108.6	128.9

*) fertilized by straw in autumn, **) fertilized by straw in spring, **1) second year crops in the same vegetative pots (fertilized by straw in spring).

Table 3 The effect of Lumbricidae (*Allolobophora caliginosa*) on the barley crops in different soils

Number of variants	Time of experiments and the variants	Reiteration number of the variants	Mean number for a variant			
			crops of the plant parts above the soil		grain crops	
			g	%	g	%
	1965.VII.4—1966.VIII.					
1	Vr — control	5	11.2 ± 0.8	100.0	5.1 ± 0.5	100.0
2	Vr 4 earthworms	5	15.0 ± 0.8	134.0	6.8 ± 0.1	133.3
3	Vr 8 earthworms	5	14.3 ± 1.3	127.5	6.7 ± 0.6	131.3
4	Vr 16 earthworms	5	16.9 ± 1.2	150.1	7.5 ± 0.2	147.0
	1966.V.11—VIII.					
1	Vr — control	3	9.4 ± 0.2	100.0	4.1 ± 3.0	100.0
2	Vr 4 earthworms	3	11.5 ± 0.2	121.9	5.7 ± 0.2	139.0
3	Vr 8 earthworms	3	13.6 ± 0.5	144.2	6.5 ± 0.0	158.5
4	Vr 16 earthworms	3	14.8 ± 0.3	154.9	7.1 ± 0.2	173.1
	1965.X.20—1966.VIII.					
1	V*) — control	5	20.2 ± 2.4	100.0	7.7 ± 0.3	100.0
2	V*) 4 earthworms	5	23.0 ± 1.5	113.6	9.9 ± 0.3	128.2
3	V*) 8 earthworms	5	30.6 ± 2.5	151.3	13.9 ± 1.2	165.5
4	V*) 16 earthworms	5	36.5 ± 2.2	181.4	16.0 ± 1.6	205.0
	1965.X.20—1967.VIII.					
1	V**) — control	4	6.1 ± 1.5	100.0	2.6 ± 1.0	100.0
2	V**) 4 earthworms	4	10.1 ± 1.0	165.7	4.9 ± 0.2	191.7
3	V**) 8 earthworms	4	15.1 ± 1.3	247.6	7.3 ± 1.1	287.4
4	V**) 16 earthworms	4	13.9 ± 2.0	227.3	6.5 ± 1.0	255.7
	1967.V.5—VIII.17					
1	K — control	5	3.8 ± 0.7	100.0	1.8 ± 0.4	100.0
2	K 4 earthworms	5	5.4 ± 0.2	141.3	2.7 ± 0.1	153.3
3	K 8 earthworms	5	8.1 ± 0.2	211.2	4.3 ± 0.3	241.0
4	K 16 earthworms	5	10.7 ± 0.3	279.6	5.4 ± 0.3	301.1
	1967.V.5—VIII.17					
1	M — control	5	6.6 ± 0.6	100.0	3.2 ± 0.4	100.0
2	M 4 earthworms	5	6.6 ± 0.3	100.0	3.2 ± 0.6	100.0
3	M 8 earthworms	5	7.1 ± 0.4	107.2	3.4 ± 0.6	107.5
4	M 16 earthworms	5	9.6 ± 0.8	144.8	4.7 ± 0.4	146.2
	1967.V.5—VIII.17					
1	Dr — control	5	12.7 ± 0.8	100.0	6.5 ± 0.5	100.0
2	Dr 4 earthworms	5	13.7 ± 1.1	107.8	6.8 ± 0.5	104.4
3	Dr 8 earthworms	5	14.2 ± 0.8	111.7	7.1 ± 0.5	108.6
4	Dr 16 earthworms	5	17.1 ± 1.0	134.2	8.4 ± 0.6	128.9

*) — fertilized by straw in autumn, **) — fertilized in the same vegetative pots by straw for the second time in spring.

also positive and in some kinds of soil (V) the effect of Lumbricidae became still greater (Fig. 2, Table 2).

The effect of Lumbricidae on the barley crops differs in different kinds of soil. This divergent effect of Lumbricidae on the plant crops is caused by the differing survival time of the earthworms in the vegetative pots. The fact is that there are some soils where the survival chance of the earthworms is greater while other soils provide poor habitats for earthworms.

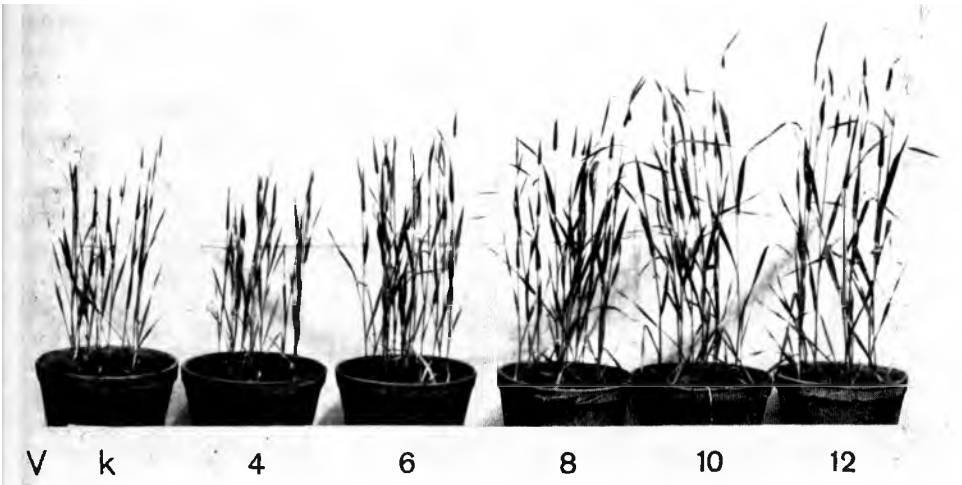


Fig. 1. The effect of Lumbricidae (Ac) on the barley crops during the third year of vegetation (May 1963—June 1965); V — soil; k — control (no earthworms); the numbers of Lumbricidae in the vegetative pots were 4; 6; 8; 12. These explanations also refer to Figures 2, 3, 4.

The number of Lumbricidae and their specific characters play also their corresponding roles in the survival of the earthworms in the vegetative pots. When there were 4 specimens of *Allolobophora caliginosa* in each vegetative pot for 2 years, the survival of the earthworms in the soil V fluctuated from 60 to 90 per cent; the survival of 8 and 16 earthworms in a pot was somewhat lower (45—70 per cent and 40—65 per cent respectively). *Lumbricus rubellus* and *Lumbricus terrestris* had a considerably lower survival (the figures for 4; 8 and 16 earthworms in a pot were 30; 26 and 18 per cent respectively).

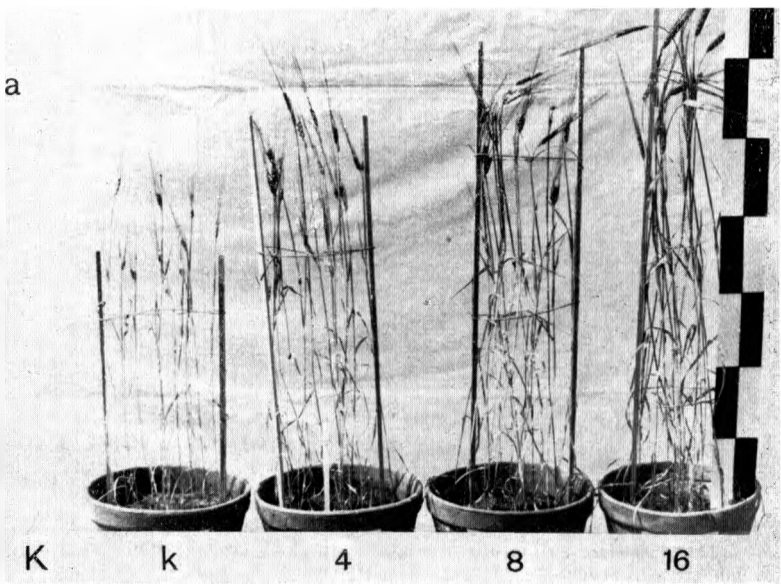


Fig. 2a

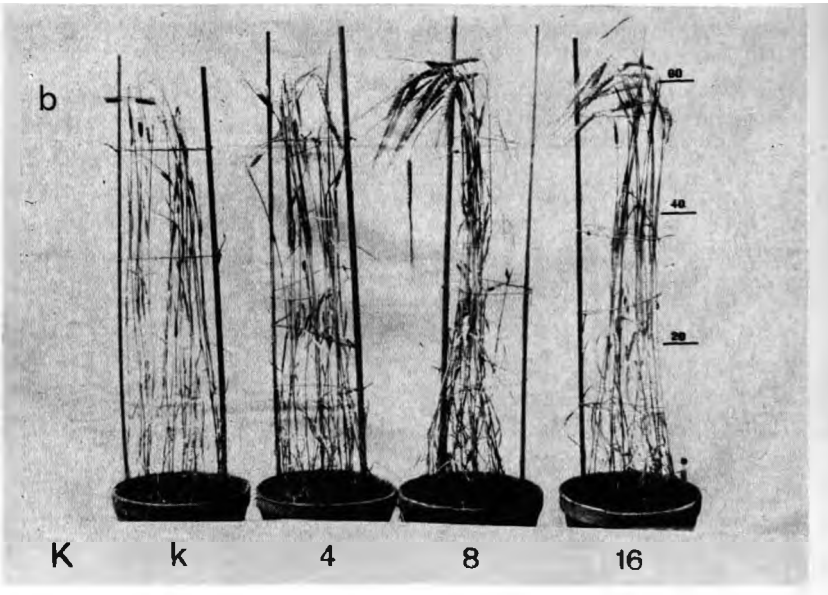


Fig. 2b

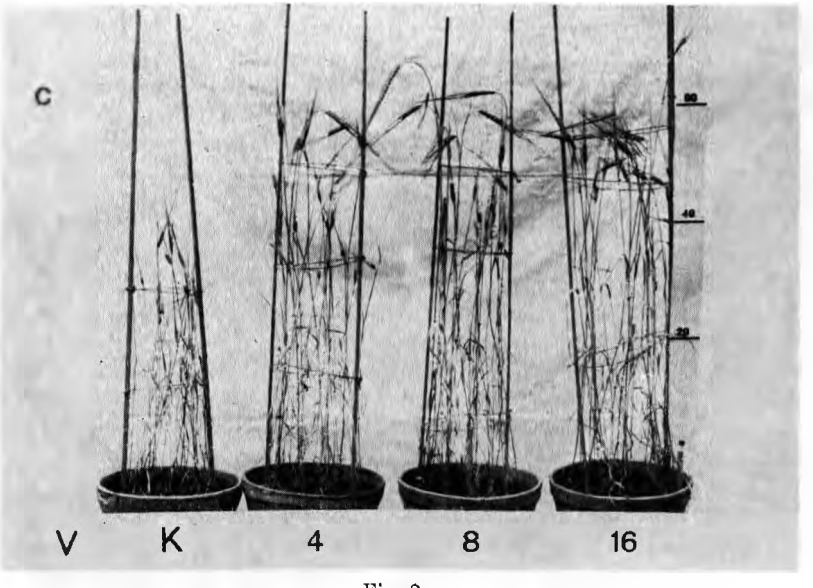


Fig. 2c

Fig. 2. The effect of Lumbricidae (Ac) on the barley crops in May—July 1967; K — soil; a — in the soil withour fertilization; b — in the soil fertilized by straw; c — in the soil V fertilized by straw (in the spring of the second year).

To investigate how the soil conditions acted on the survival of the earthworms in the vegetative pots we have kept the latter in soils: 1) below the plants (barley), 2) with no plants above, 3) in similar conditions as indicated above but fertilizing the soil by straw

and 4) cultivating the plants and fertilizing the soil by straw (Fig. 3). It was found that by keeping the earthworms under the above-mentioned conditions during one vegetative season (May—October) higher survival occurred among those earthworms living in pots without plants. The best survival was noticed in the soil Vr where no plants had been cultivated but the soil was fertilized by straw. In the vegetative pots with such soil, tiny young Lumbricidae appeared and their number was on the increase. But in the soil K which was fertilized by straw and in which barley was cultivated the survival of Lumbricidae was almost equal to that of the pots with unfertilized barley. The lowest survival of Lumbricidae under barley was noticed in the soils M and Dt. The effect of the earthworms on the barley crops was also minimal in these soils in 1967 (Table 3, Fig. 4). The decrease of the effect of Lumbricidae on the barley crops in some cases can also be explained by the low survival of the earthworms (Table 2).

There is sufficient ground to suppose that higher survival of Lumbricidae in the vegetative pots without barley was made possible by the more constant soil humidity there. In spite of equal watering of all the pots the soil with plants evaporated more water than that without them. On the other hand, the fertilization by minced straw gave Lumbricidae additional nourishing elements.

Greater effect of the earthworms on the barley crops and higher survival of Lumbricidae in the vegetative pots were observed in those soils which were less acid (pH 5.3—6.9) and had more humus (2.4—7.2 per cent).

In order to gain a deeper knowledge of the effect which the earthworms have on different kinds of soil and to use such knowledge for better crop production, there is an urgent need to investigate further the biology and ecology of the earthworms.

4. Conclusions

The positive effect which Lumbricidae have on crops was shown by the experiments carried out in vegetative pots. There was an increase in barley crops in accordance with the increase in the numbers of Lumbricidae. As compared with the control data the maximum crop increase figures registered for the pots with 4; 8 and 16 earthworms in them were 91,7, 187.4 and 201.1 per cent respectively.

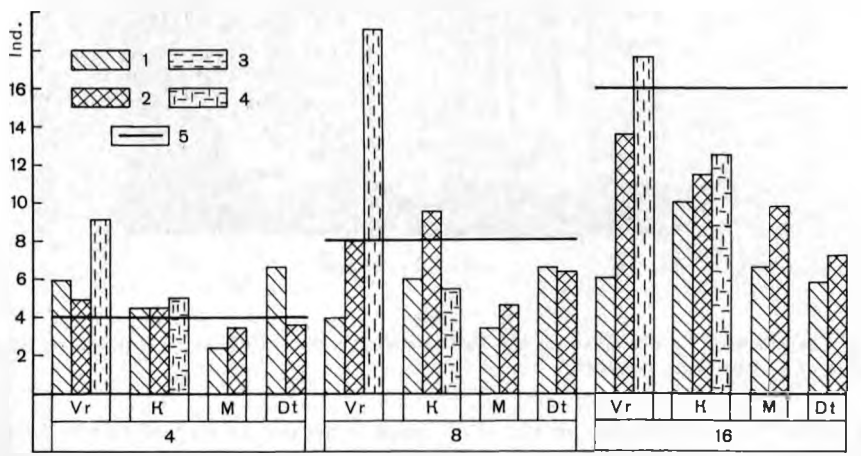
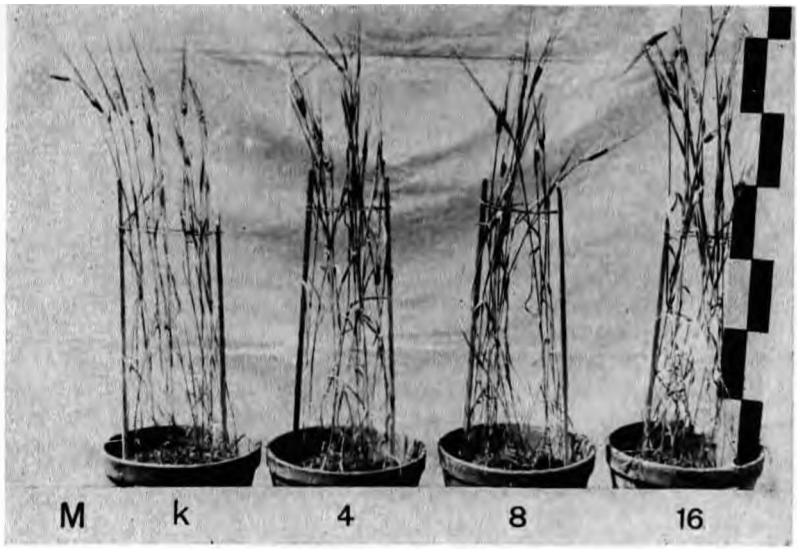


Fig. 3. The survival of Lumbricidae in the different vegetative pot soils: Vr — May—October 1966; K, M, Dt — May—Oktober 1967; 1 — in the soil under barley; 2 — in the soil with no plants; 3 — in the soil having no plants and fertilized by straw; 4 — in the soil under barley and fertilized by straw; 5 — the numbers of Lumbricidae at the beginning of the experiment.



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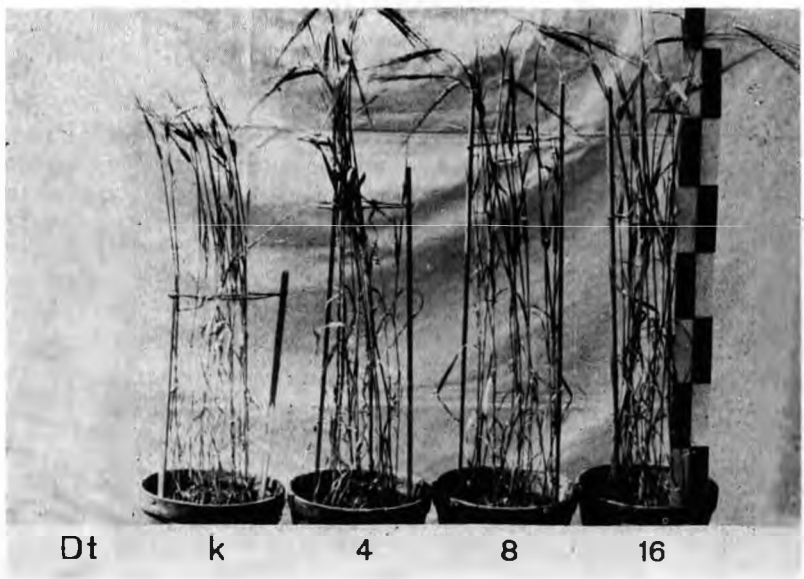

4b

Fig. 4. The effect of Lumbricidae on the barley crops in the soils M and Dt in which the least numbers of Lumbricidae survived.

The effect of Lumbricidae on the plant crops is greater in respect to the weight of grains than to the weight of the total green mass of the plants. The effect of Lumbricidae on barley crops varied in the different soils and depended on the survival of the earthworms in the vegetative pots. Lumbricidae survived better when the soils contained more humus (2.4—7.2 per cent) and were less acid (pH 5.3—6.9). The survival of Lum-

bricidae also depended on their number and their specific characteristics. The best survivors were *Allolobophora caliginosa* (40—90 per cent) followed by *Lumbricus rubellus* and *Lumbricus terrestris* (both 18—30 per cent). The effect of Lumbricidae on the crops increased and the survival of the earthworms was enhanced when soils had been fertilized by straw.

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